Science, astronomy, and sacrifice zones: development trade-offs, and the Square Kilometre Array (SKA) radio telescope project in South Africa

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## Introduction

After 1994, post-apartheid South Africa committed to a strategy in which Science and Technology (S&T) policy has been geared towards two main objectives. The first, premised on the progressive power of S&T to unleash the country's productive forces, is for participation in the global knowledge economy to serve as a motor of economic development. The second is for innovation in S&T to be directed at overcoming the legacy of apartheid and addressing socio-economic challenges as part of the country's transformation agenda. These principles were first outlined in the 1996 *White Paper on Science and Technology* (DACST 1996) and reaffirmed in a new White Paper that was released for comment in 2018 and adopted as policy in 2019 (DST 2018, 2019).[1]

In high-level policy statements these two objectives are presented as intertwined and mutually reinforcing. In the National Planning Commission's 2011 *National Development Plan Vision for 2030*, success in "creating a virtuous cycle of growth andevelopment" is linked very clearly to the extent to which "the lives and opportunities of the poorest South Africans are transformed in a sustainable manner" (NPC 2011, 1, 2). With specific reference to S&T the National Research Foundation's *2020 Strategy Document* (NRF 2019, 4) commits to "facilitate the creation of knowledge, innovation, and development in all fields of science and technology, including indigenous knowledge and thereby strengthen the relationship between science and society to contribute to the improvement of the quality of life of all the people of the Republic". Innovation in S&T is expected to build a dynamic and competitive economy while also addressing the societal challenges inherited from the country's past. The vision of the 2019 S&T White Paper – "science, technology and innovation enabling inclusive and sustainable development in a changing world" – captures this perspective succinctly (DST 2019, 11).

In this article, we question the assumption of a seamless and self-evidently positive relationship between S&T and "inclusive and sustainable development" by looking at one of South Africa's flagship science projects, the Square Kilometre Array (SKA) radio telescope, currently under construction in the semi-arid Northern Cape Province. Astronomy has been identified as a significant field of scientific endeavour in which post-apartheid South Africa has a competitive advantage (DST 2002), and the SKA is widely hailed as an exemplar of excellence and success in otherwise troubling times (see, for instance, Wild 2012; Gastrow 2017; Bhogal 2018; Jenvey 2018; Atkinson 2019). In his February 2019 State of the Nation address, President Ramaphosa praised the project and the developmental benefits of S&T as follows:

> Today, we choose to be a nation that is reaching into the future. (. . .) The successful construction in the Northern Cape of the MeerKAT[2] has enabled South Africa to develop capabilities in areas such as space observation, advanced engineering and supercomputing. (. . .) This is not merely about advancing human understanding of the origins of the universe – it is about responding to the challenges that face South Africans now and into

> the future. It is about developing the technology and the capabilities that will build a dynamic and competitive economy that creates decent, sustainable jobs. It is about enhanced food security, better disease management, and cheaper, cleaner and more efficient energy. It is about smart human settlements and social development solutions built around people's needs and preferences. It is about smarter, more responsive, more effective governance. (Ramaphosa 2019)

However, closer scrutiny of such claims reveals tensions that warrant deeper analysis as well as more refined policy development. These tensions operate both at the level of principle – the emphasis on universally positive development spin-offs, without acknowledgement of the competing interests and intractable trade-offs often involved in addressing "people's needs and preferences" – and at the level of practice, in project-specific local offset and community development programmes attached to major S&T projects.

Once one asks the question, "Development for whom?", the twinned objectives of the "development of science" and "science for development" are no longer so neatly aligned.

The SKA is a case in point. The promotion of astronomy in the Karoo has, we argue, rested on a notion of development which assumes that what are defined as national and global interests, encapsulated in the notion of "the public good", either subsume or supersede local interests. In a recent special issue of the *Journal of Southern African Studies* we have argued that, against a history in which the roots of modern astronomy in South Africa lie in the country's colonial past, the development of the SKA in the long-marginalised Karoo region raises "significant conceptual, theoretical, methodological and ethical challenges . . . across different scales and registers of analysis" (Walker, Chinigò, and Dubow 2019, 627). From several disciplinary angles contributors to the special issue explore, *inter alia*, the tensions around the relationship between space, place, and time in the configuration of the Karoo as a major astronomy site, the role, and responsibilities of the national and local state, and the politics of knowledge, including how to understand the cultural artefacts produced by the study of the cosmos. What is clear is that, however, one evaluates its benefits, the SKA is an externally conceived and driven project that has been developed on top of, not emerged out of, local needs, aspirations, and preferences. From its inception it has been embedded in unequal power relations.

The core beneficiaries of this extraordinary big-science project are powerful constituencies in faraway metropoles (national and international), not the marginalised people living in its neighbouring host communities. To the extent that local development issues have been factored into its planning, the *modus operandi* to date has been based on an essentially top-down and technocratic appraisal of local needs, viewed primarily through the lens of improved science communication and education (Gastrow and Oppelt 2019; Atkinson 2019). This approach has articulated poorly not only with the many pressing socio-economic challenges facing local residents in its neighbouring communities but also with their understandings of the region's past and their aspirations for the future. Measured in these terms, the local education and economic opportunities that have been created thus far are seen as insufficient. Equally significant is that they have not been designed to carry such a burden, as local development is not the SKA's central mandate (Gastrow and Oppelt 2019; Atkinson 2019). As we have argued elsewhere, the disjuncture between national and local interests raises important questions about scale – at what scale are "the public good" and national development outcomes to be measured and success declared (Walker and Chinigò 2018)? The view from Johannesburg or Cape Town or Manchester (the UK headquarters of the international SKA project) is not the same as the view from a street within a small Karoo town or a farmhouse or workers' cottage on

a farm.

In this article, we take this discussion further by addressing more directly the questions we and others have raised, about how the benefits from this global mega-project should be distributed, and what responsibilities lie with the SKA, nationally and internationally, for addressing local concerns. We do so by posing a further and more provocative question: In the light of the evident disjuncture between national and international investment in the SKA on the one hand, and local priorities on the other, should the farmlands and small towns around the SKA core site be better understood not as sites for "development" but, rather, as astronomy's "sacrifice zone"? Posing the question in such stark terms, we propose, brings critical but neglected questions about mitigation (rather than collateral benefits) into focus and opens up a new and potentially more constructive conversation around what mitigation involves, who is responsible for it and how that mandate gets taken forward.

The notion of sacrifice or sacrificial zones has emerged most forcefully in the literature on environmental justice, to capture the cost to local communities and ecologies of the destructive social and environmental impacts of many "development" projects, in particular extractive industries such as mining and the armaments industry. (See, for instance, Bebbington and Bury 2013; Breglia 2013; Lerner 2010; Vasquez 2014; Hernández 2015; Holifield and Day 2017). The concept, which was applied originally "to areas made uninhabitable by nuclear fallout" during the Cold War (Holifield and Day 2017, 269), has also been drawn on in debates among rangeland ecologists in assessing the damaging consequences for local ecosystems of concentrated livestock holdings around, for instance, watering points, where the negative impact of stock trampling on these "sacrifice zones" may be justified by the benefits to farmers and their animals. (See, for instance, Perkins 2018; Riginos and Hoffman 2003). The concept is not commonly applied to areas where the natural environment appears not to be directly affected – indeed, in the case of the SKA, the declaration of its core site as the "MeerKAT National Park" (RSA 2020), dedicated to "scientific research or environmental monitoring" in terms of South Africa's Protected Areas legislation (RSA 2004, section 18(2)*(b)*), has excited many environmentalists who are concerned at how little land in the Nama Karoo is under conservation management (Hoffman et al. 2018).

However, we think that the notion of sacrifice zones can be usefully applied to the SKA in the Karoo in two interconnected ways. First, characterising this area as a sacrifice zone brings into sharp relief the magnitude of the land use change that is underway and the profound reconfiguration of local livelihoods and ways of life it has initiated. Second, the concept of sacrifice zone captures the uncertainties about the local risks that this reconfiguration involves, which the dominant discourse about win-win development scenarios and science in pursuit of the greater good, for the benefit of all, obscures. The concept of sacrifice zones serves to interrogate the politics of knowledge and the power relations involved in the institutionalisation of a big-science project in this politically and economically marginalised region of South Africa. Recasting the Karoo as astronomy's sacrifice zone raises challenging questions about whose Karoo it is and where the power to define the future of the Karoo does and should reside (Walker, Chinigò, and Dubow 2019). It redirects attention from the grandeur of the SKA project and what it promises "humankind" to the specificities of the marginalised places where it is being built and what may be sacrificed and by whom. Here what needs noting is that it is not simply current livelihoods and social dynamics that are at issue but the alternative futures and local opportunities for shaping them that are being foreclosed.

In sum, the notion of sacrifice zones focuses attention very sharply on the extent to which the views and priorities of residents now living in the shadow of this project have been subordinated – trampled upon, if you will – for the benefit of others, in the name of the greater good. From this perspective, the establishment of the MeerKAT National Park at the heart of the SKA's "sacrifice zone" is consistent with important features of what political ecologists have defined as "fortress conservation" (Brockington 2002; on this see also Walker 2019). Unpacking the power dynamics underlying the creation of protected areas, various studies have analysed how exclusionary conservation practices often reflect metropolitan aspirations and interests that are not aligned with local development priorities (Cole and Foster 2001; Barrett, Travis, and Dasgupta 2011). Conflict over conservation areas reflects dynamics of race and class that emerge alongside the construction of these selected environments as "natural", based on a rigid separation between nature and society (Cock 2007). In the case of the SKA these exclusionary mechanisms have brought the physical and natural sciences into an alliance, providing further legitimacy for the development of astronomy for the greater good. Thinking about the local impacts of the SKA in terms of sacrifice zones also raises important questions about the meaning and scope of the commitments to inclusive and sustainable development that are outlined in the country's strategic policy documents. What should this commitment mean in an historically marginalised region of the country that outsiders have designated the locus of a globally networked big-science project, one which is not only remote from local people's daily needs but is imposing various restrictions on everyday technologies (including, as discussed further below, cell phones and petrol-driven cars), because of the need to protect the project's powerful yet vulnerable science agenda against harmful radio frequency interference?

Holifield and Day (2017, 270) have drawn attention to the two "major dimensions" along which the "meanings of sacrifice and the sacrifice zone vary": "the object of sacrifice and the initiator of sacrifice". With regard to the object, in this article we are using the concept of sacrifice zone to shift the debate on the local impacts of radio astronomy in the Karoo from one in which they are assessed as by-products (whether good or bad) of a broader national and global vision, to one that scrutinises them first and foremost in relation to the region's social and economic marginality; this requires a critical engagement with the historical, social, and environmental dynamics in which this marginality is embedded. This shift involves a set of second-order questions, which we touch on in our conclusion, which foregrounds the responsibilities of the "initiator" of the "sacrifice": given the marked power imbalances, can more broad-based local returns be leveraged from this investment in global science? If not, how can the trade-offs be mitigated (in policy and in practice) and where does responsibility for this mitigation lie – with the science project itself or the state or the international astronomy community at large or some combination of all three? If it is with the drivers of the big-science project, then at what level: international or national? Equally, if it is with the state, at what level: national, provincial, or local? In all cases: how can local people be fully involved in determining their needs, preferences and priorities?

These are not easy questions to answer. Nor are they unique to the case of the SKA, nor of astronomy more generally – similar questions are also emerging in relation to major investments in renewable energy projects currently unfolding across the Northern Cape, where many impoverished households are struggling to see clear local benefits, whether in the form of significant job opportunities or access to (in President Ramaphosa's words) "cheaper, cleaner and more efficient" household energy.[3]

However, these questions arise with particular intensity in relation to the SKA, in part, we would argue, because of the aura of scientific purity and being above messy earthly politics that envelops astronomy as a human endeavour.

We develop our argument as follows. In the next section, we outline the history of the SKA against the backdrop of South African astronomy's colonial roots and efforts to break with that in the country's post-apartheid S&T strategy (the development of astronomy).[4] Thereafter, we draw on the notion of sacrifice zones to explore elements of the SKA's institutionalisation and understanding of the contribution of astronomy to development, including in its host – or perhaps, more accurately, satellite – communities (astronomy for development). We conclude that, if a more sustainable and inclusive development agenda in the Karoo is a serious concern, then the evident tensions between advancing astronomy and advancing local development in the SKA's "sacrifice zone" need to be addressed explicitly, not only at project level but also in the conceptualization of wider S&T policy. This requires putting the issue of mitigation for the trade-offs that local people are expected to accept at the forefront of the project's development mandate; in our conclusion we propose four issues that need attention to moving in this direction. The article is based on qualitative fieldwork and documentary analysis conducted within the South African Research Chair in the Sociology of Land, Environment, and Sustainable Development at Stellenbosch University, supplemented and enriched by critical engagement with other scholars working on related themes.[5]

## The SKA and the development of astronomy

The SKA is a global endeavour to build the world's largest radio telescope, making it one of the most ambitious investments in "big science" of the new millennium. First broached as an idea in the early 1990s, the project currently involves a core of member countries (13 in October 2020), 7 of which signed an international treaty establishing the global SKA Observatory as an International Government Organisation in March 2019[6]; the full project involves a much larger network of participating research institutions and partner countries. Its two main infrastructural hubs are located in Murchison Shire in Western Australia and in the semi-arid Nama Karoo region of South Africa's Northern Cape Province, some 90 kilometres north-west of the small town of Carnarvon. Currently, this site is the locus of the South African funded 64-dish MeerKAT telescope,[7] which was built as a precursor to the SKA proper; the latter is due to be rolled out in a phased approach over the coming decade. The core site covers some 130,000 hectares of former sheep farms (now the MeerKAT National Park) that the state acquired through an acrimonious land acquisition programme that concluded in 2018.[8] However, as discussed further below, the impact of the SKA extends far beyond this site, across a set of concentric "Astronomy Advantage Areas" that the state has declared around the core site, that cover some 123,000 square kilometres. When completed, the infrastructure in and around the core site will comprise some 200 radio dish antennas, all linked to each other, and receivers in other sites around the globe by means of an incredibly sophisticated IT network,[9] thereby making up the full square-kilometre array.

Globally, the SKA is heralded by its advocates as at the forefront of humankind's quest to unravel the mysteries of the universe. Within South Africa, the Ministry of Science and Technology promotes the SKA primarily through a national narrative about the progressive role of S&T in the development trajectory of the country since the advent of democracy in 1994: now, for the first time in modern history, a globally significant

science project, one that will transform the ways in which we understand basic science and answer fundamental questions about the universe and the future of humanity, is being conducted in Africa, from South Africa. In this formulation, the SKA marks a significant moment of rupture with South Africa's oppressive past. It affirms the country's standing in Africa and the wider world, while creating extraordinary new opportunities for domestic social and economic development – thus a win-win scenario all round.

The relationship between contemporary astronomy and its past is, however, rather more ambiguous than this telling suggests. Historically the development of astronomy in South Africa has been deeply implicated in the project of British imperialism, starting with the establishment of the Royal Observatory at Cape Town in 1820, with a primary purpose to advance applied science in maritime navigation, time-keeping and terrestrial mapping within and for the British empire (Dubow 2019). As further noted by Saul Dubow (2019), South Africa's astronomy facilities have long served as "viewing platforms" for northern astronomers. From the 1960s, in the context of the growing international isolation of the apartheid state, state investment in local capacity in astronomy received increased attention, with the establishment of the South African Astronomical Observatory's (SAAO) optical astronomy facility at Sutherland in the southern Karoo in 1973 a prime example. This did not, however, mean that international collaboration in astronomy was completely discontinued, and after the end of apartheid this resurfaced with increased vigour.

The advent of democracy saw a concerted drive by elements within the African National Congress (ANC) political elite to distance astronomy from its colonial underpinnings and reposition it as a progressive force with an important role in building the country's future. Two visionary astrophysicists with a history of activism in the national liberation struggle (Bernie Fanaroff and Rob Adam, the former and current directors of the SKA project in South Africa) were appointed to leading positions in the new government's bureaucracy, from where they played pivotal roles in advancing the development case for astronomy within a revisionist account of how S&T would contribute to building the "new" South Africa. The opening of the Southern African Large Telescope (SALT) at Sutherland in 2005, and the country's investment in the international SKA project from the early 2000s, are widely acclaimed examples of the ruling party's success in positioning South Africa as a valued contributor to the global knowledge economy. These developments were central to the branding of astronomy as a success story for South Africa, one that could lead the way to economic growth and development, not least by inspiring new generations of South African scientists. (On this see Gastrow 2017; McBride et al. 2018).

In identifying astronomy as one of the country's flagship sciences in the early 2000s (alongside human palaeontology, conservation biology and Antarctic research), the DST (2002) emphasised the country's "geographic advantage" with regard to astronomy, rather than its "knowledge advantage" deriving from its pre-democracy legacy. The geographic advantage in relation to astronomy is twofold. Scientifically the location of the country in the southern hemisphere enables the astronomical observation of the less explored southern sky, and offers a privileged viewpoint for observing the galactic centre of our own galaxy, the Milky Way, along with other astronomical phenomena only visible from the southern hemisphere. At the same time, South Africa's western interior, with its low population density, aridity, and elevation, along with its modicum of modern transport and electricity infrastructure, has long been identified by astronomers as

offering excellent conditions for astronomical observation.

Significant here for thinking about astronomy in relation to sacrifice zones, are the steps taken by the South African government in the early 2000s (before its bid to host the SKA had succeeded) to ensure that this geographic advantage would be safeguarded by means of special legislation, the Astronomy Geographic Advantage Act (RSA 2007). This Act was carefully designed to quarantine not simply the areas around key infrastructural nodes such as SALT and the SKA but almost the entire Northern Cape Province – 30% of the country by area – from other developments deemed potential threats to the pursuit of astronomy. It empowers the Minister of Science and Technology "to regulate activity which cause or could cause light pollution or radio frequency interference or interfere in any other way with astronomy and related scientific endeavours" (RSA 2007, section 2 *(e)*), and specifies a range of activities that could be regulated in this regard, including cell phone development, mining, electricity generation and transmission, airfield development, the construction of new housing, business and recreational areas, and road or rail development (section 23(1)).

From the perspective of local economic development this is an extraordinarily extensive, hence restrictive, list – yet the legislation seems to have been passed with little if any debate at national, provincial, or local level about its implications for "inclusive and sustainable development" in the Karoo into the future.[10] The Act can be applied to the entire Northern Cape province, with the exception of the provincial capital of Kimberley; to date, as already indicated, several concentric Astronomy Advantage Areas (AAAs) (RSA 2014b), each with their own regulatory requirements, have been declared around the core site of the SKA, outside the town of Carnarvon, and one around the South African Astronomical Observatory (SAAO) site outside the town of Sutherland where SALT is located (see Figure 1).

### *Decolonising astronomy*

President Ramaphosa's 2019 speech quoted earlier exemplifies the official view of the relationship between astronomy and national development in post-apartheid South

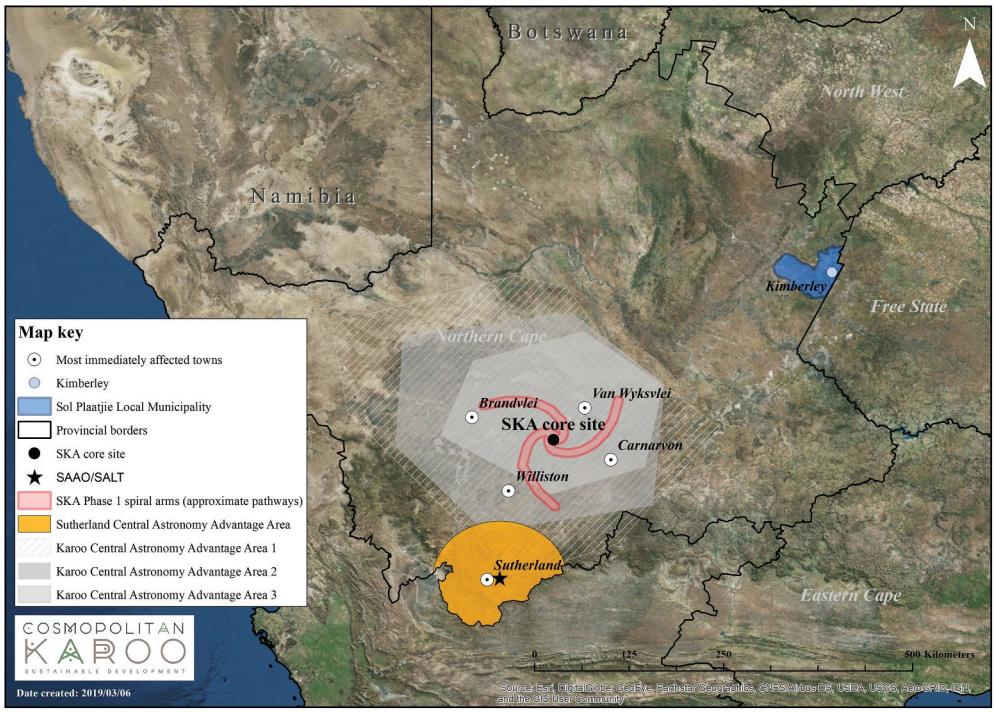


**Figure 1. Major astronomy sites and gazetted AAAs in the Northern Cape Province.**

Africa, one which mirrors the government's position on S&T policy more generally: the relationship between the development of astronomy and astronomy for development is a symbiotic one. The investment in astronomy is justified in part by the very grandeur and scope of the SKA project's science mission, aimed as it is at probing the mysteries of the universe further back in space and time than any other astronomy project to date. At the same time, while the development of astronomy is about answering fundamental questions about the nature of our universe, what is also emphasised by the project's advocates is that answering these questions requires the development of scientific capabilities and technologies that will, in turn, promote national economic development. Astronomy in general and the SKA in particular are operating at the forefront of the digital data revolution – according to the SKA website, processing "the vast quantities" of data that the project will produce will require "a trillion times more computing power than sent mankind to the moon" (SKA n.d.) – and the technological spin-offs from this are expected to fuel a more dynamic and competitive national economy. In this regard, the 2018 draft *White Paper on Science, Technology and Innovation* draws attention to the importance of South Africa's participation in the so-called "Fourth Industrial Revolution" and exploitation of new sources of economic growth through ICT and big data (DST 2018, 4, 12). The final version of the White Paper that was adopted in March 2019 made the link between South Africa's investment in the SKA and the "beneficiation potential" of big data explicit:

> South Africa is a rich source of research data and has made substantial investments in cyberinfrastructure, as well as in the acquisition and generation of data across a number of domains. Driven by initiatives such as the Square Kilometre Array (SKA), these commitments are set to greatly increase in the future and uniquely position South Africa to derive substantial benefits from big data. South Africa, however, should not just be a collector of data. The economic, social, scientific and industrial beneficiation potential of big data for South Africa must rather be realised. (DST 2019, 17)

These two threads – that the development of astronomy is important both in itself and for its contribution to development – are woven together through the many overlapping claims attached to the SKA as a flagship project. A prominent theme is the celebration of the role of South Africa and its scientific community in the advancement of global scientific knowledge production, through fundamental research in astronomy, but this is consistently tied to more instrumentalist concerns. Seen as building South African capacity not only in basic science but also in the fields of technology, engineering, and computing, the SKA is hailed for marking an epistemological shift in the country's understanding of itself in the world, moving effectively from a state of "brain drain" to one of "brain gain."[11] At another level, the SKA gives credence to an otherwise faltering narrative, embedded in the political history of the ANC, of South Africa as a developmental state committed to a modernising agenda (Atkinson 2019).

The SKA as a global project in fundamental science also embodies wider ambitions to reshape the African continent's relationship to global S&T, while positioning South Africa at the forefront of this endeavour. The commitment to building a future generation of scientists that can bring the country together through science reflects much of the universalism embedded in Mbeki's vision of an "African Renaissance" (Mavimbela 1998). Inspired by the ideals of pan-African humanism, South African proponents of the SKA project have pushed from the start for its extension across the African continent. Once completed, the full Array is projected to reach into a further eight African countries (Botswana, Ghana, Kenya, Madagascar, Mauritius, Mozambique, Namibia, and Zambia), under South African leadership. These countries are currently linked to the SKA as "African partner countries" through the African Very Long Baseline Interferometry Network (AVN), a project sponsored in large part through the African Renaissance and International Cooperation Fund (ARF) from the South African Department of International Relations and Cooperation.[12] The purpose of the AVN is to "help to develop the skills, regulations and institutional capacity needed in SKA partner countries to optimise African participation in the SKA" (AVN n.d.).[13]

Yet, there are significant ambiguities in the case for astronomy as a force for the decolonisation of knowledge that we can merely flag here. On the one hand, the SKA is framed as a game-changing project for transformation, reversing historical North-South power dynamics and liberating "African knowledge" from its colonial underpinnings. On the other hand, the SKA is building on a scientific legacy that is deeply rooted in the country's and the continent's colonial past, one that more radical views of what decolonising knowledge entails are keen to dislodge. Thus, much more than geographic advantage is involved in why South Africa enjoys a competitive advantage in astronomy. Furthermore, and of more immediate significance in terms of the country's current S&T strategy, the development of astronomy in South Africa remains heavily reliant on the international dimensions of the SKA project in terms of northern funding and northern expertise. This is not to deny the significant investment South Africa has already made in the project – projected to rise from some R4 billion by 2018/19 to some R10 billion by

project completion (RSA 2019, 44). Nor is it to diminish the stature of individual South African astronomers. However, a central narrative justifying this financial commitment to taxpayers is that the bulk of the investments in the SKA proper will come from international resources and, considering the current membership of the international consortium, primarily from European countries.[14] At the same time, it is significant that the Array's main output will be in the form of digital data that can be accessed from anywhere in the globe, with the appropriate ICT infrastructure; what this means is that the primary users of the data in research institutions in the north do not have to come to South Africa to access it. It is thus questionable whether the SKA's core site in South Africa represents a clean break with earlier configurations of the country's contribution to astronomy as lying principally in its status as a "viewing platform" for astronomers in the North.

> Thus, despite the political claim that the development of astronomy in post-apartheid South Africa represents a significant rupture with the past, the SKA project reflects continuities as much as discontinuities with that past and its ongoing manifestations in the contemporary world. The ambiguities in the narrative of the development of astronomy at the national and international level re-emerge in the tensions between local and national development priorities in the narrative of astronomy for development, to which we turn in the next section. Here, what the emphasis on the benefits of the SKA project either overlooks or obscures are the costs that are attached to it at the local level – the uneven impact, on the ground, of radio astronomy as not simply a pure, celestial science but a globally networked industry with a marked and very distinctive earthly footprint.

In the next section we develop this argument, first briefly reviewing key moments in the rollout of this project after 2012 and the local conflicts this generated, and then elaborating on two significant features of the SKA in the Karoo that support the characterisation of it as astronomy's "sacrifice zone." The first is the projection of emptiness as a defining characteristic of the SKA's core site; the second is the dominant understanding of local development concerns among the project's managers as effectively an extension of global and national priorities.

## The SKA and astronomy for development: the Karoo as a sacrifice zone?

The assumption that "astronomy for development" follows consequentially from the "development of astronomy" was probably at its most hegemonic in relation to the SKA in 2012, the year when the international bid process to host the SKA's physical infrastructure was concluded. This saw the award being split between South Africa and Australia, with South Africa selected to host two of the three components of the international project (its high- and mid-frequency dish antennas).[15] Despite grumblings around the politics shaping the final decision, the outcome was widely celebrated in South Africa as a success for the country and the African continent more broadly (Wild 2012; Gastrow 2017). Bernie Fanaroff, SKA South Africa Project Director at the time, commented to the BBC that:

> [the decision] means that for the first time in our history, Africa will be the host to the world's largest scientific instrument. And it shows a great deal of faith by the rest of the world in our ability and our capacity to both build and operate such a sophisticated instrument. It also reflects the recognition in Africa of how important science and technology is to our future. (Amos 2012)

2012 was an optimistic time in the relationship between the SKA and residents in its

satellite towns as well. This was a moment when high expectations were being generated about what the project would deliver for the small, economically challenged towns in closest proximity to the core site – Vanwyksvlei, Carnarvon, Williston, and Brandvlei.[16] These four towns were described by the authors of the Socio-Economic Assessment Report commissioned by the SKA as having "typical rural problems of poverty, unemployment and social inequality . . . with around 70% of households receiving grants from government as a main or supplementary income" (Atkinson, Wolpe, and Kotze 2017, 26). By then, South Africa's seven-antenna Karoo Array Telescope (KAT-7), a precursor to the SKA proper, had already been built on two sheep farms that the state bought for this purpose in the early 2000s, and most local people assumed both that this was the extent of the land purchases and that radio astronomy and sheep farming could coexist.[17] Weeks after South Africa won the international bid to host the international project then President Zuma visited Carnarvon, the largest of the SKA's satellite towns, which was an exceptional event for local people. The Minister of Science and Technology accompanying the President, Naledi Pandor, declared that the "SKA has put Carnarvon on the world map! Let's continue using it to make South Africans proud and to inspire young people about a future in science and technology" (Polity 2012).

Within a few years, however, the SKA's relationship with local residents had entered a much more negative and turbulent phase. Two fault-lines had appeared – first, tensions around the state's land acquisition programme between 2016 and 2018 and, second, growing mistrust among many townspeople of the SKA's intentions, as their initially high expectations of jobs and other opportunities began to founder (Atkinson, Wolpe, and Kotze 2017; Gastrow and Oppelt 2019; Terblanche 2020). Ultimately the land acquisition process by the NRF resulted in the purchase of an additional 32 farms which, when added to the 2 farms already acquired for KAT-7 and MeerKAT, brought the total area of the SKA core site to approximately 130,000 hectares. During this process confusion as to the number of farms the SKA intended to buy and the layout and number of the additional "spiral arms" requiring servitude agreements[18] exacerbated mistrust of the SKA among white farmers especially (Gastrow and Oppelt 2019; Terblanche 2020); this united both those whose farms were targeted for purchase and those not directly affected, who feared the impact that taking 130,000 hectares out of sheep farming would have on the future of commercial farming as they know it in the area.[19] A study commissioned as part of the SKA's Strategic Environmental Assessment estimated that the annual cost to the local economy would be in the region of R31 million while over 1,500 jobs would be lost overall (Kirsten 2016). The total figures included the direct loss in agricultural production (R16 million), the drop in business volumes for agricultural- related activities (R9 million), a projected 8% reduction in volumes at the local abattoirs, and the devaluation of farms on the border of the new MeerKAT National Park, in part due to the increased risk to sheep farming from the anticipated increase in predation from jackal and caracal in the adjacent reserve. Local critics emphasised the damage to an agricultural economy already facing many challenges, including the threat of climate change and severe drought, the lack of state support for commercial agriculture, and the uncertainties generated by the state's unresolved land reform programme (Terblanche 2020).

For its part, SKA spokespeople justified the acquisition process in terms of the Astronomy Geographic Advantage Act and the requirements of "the international[ly] determined design of the SKA radio telescope instrument" (SARAO n.d.).[20] While specific details are not available because of non-disclosure agreements, anecdotal evidence suggests that the compensation paid to farmers exceeded market standards (which at least some members of the astronomy community considered an undeserved windfall for these farmers, given the local history of dispossession and the wider national context of land reform). At the same time the state also chose to neutralise the perceived negativity of the local farming community by entering into a Memorandum of Agreement with Agri-SA, the national body for commercial farmers, in February 2017. This committed both

organisations "to continuously explore ways where affected agricultural land is optimised to accommodate ongoing farming activities where possible, as long as the functioning of the radio observatory is not compromised" (SKA Africa 2017) – a clear example of national politics dominating local concerns.[21]

Significantly, local discontent over the SKA was not confined to white commercial farmers, but extended to the majority of local residents living in the satellite towns (Afrikaans-speaking and "coloured" in the lexicon of apartheid). Initially, as already noted, for many townspeople the coming of the SKA to the area heralded new opportunities not only to invigorate a local economy from which they were largely excluded but also to disrupt racially exclusive hierarchies of status and power. However, as the implications of living within an Astronomy Advantage Area began to filter into people's awareness and the tangible benefits from the SKA project failed to live up to expectations, the mood among many townspeople shifted (Butler 2018; Gastrow and Oppelt 2019). Rather than a beacon of transformation, the SKA came to be seen by some prominent civic leaders as a source of duplicity, new restrictions, and uncertainty.[22] One telling example of the perceived disconnect between the SKA and the promise of transformation involves the state's land restitution programme, with a number of residents who have lodged formal but as yet unaddressed land claims on farms around the SKA core site concerned that their claims for redress will in some way be thwarted or compromised by the presence of the SKA and the restrictions on land use associated with the AAAs (on this see Chinigò 2019). From its side, SKA personnel have felt saddled with expectations around responsibilities that lie outside their core mandate. In the words of one staff member, quoted by Gastrow and Oppelt (2019, 721), "[w]e're such a major project within the area, everything becomes the SKA's fault or the SKA's problem to solve."

Key to understanding the very different logics at play is the stark contrast between the SKA as an extraordinarily sophisticated global science facility and the challenging environment in which it is being built. The semi-arid Nama Karoo region of the Northern Cape is one of the country's more marginal regions. For most South Africans, the Karoo is little more than a scrubby, thinly populated wasteland. Historically it is the heartland of the particularly brutal encounter between white settlers and indigenous Khoisan groups in the eighteenth and nineteenth centuries. Today, the local Karoo Hoogland, Hantam, and Kareeberg municipalities are plagued by poverty and unemployment, heavy dependence on government social grants and disturbingly high levels of substance abuse, teenage pregnancy, and high school drop-out rates (Walker et al. 2018; Vorster and Eigelaar-Mets 2018). Social relations still reflect strongly racialised social hierarchies and inequalities. A small and relatively wealthy white elite controls the commercial sheep farming sector (historically the region's main economic activity) and major local businesses, including the retail and hospitality business opportunities arising from the SKA. The majority of people constitutes a depressed underclass.

Against this background, characterising the area around the SKA core site as a sacrifice zone highlights the trade-offs at stake in the two very different sets of development priorities at work: on the one hand, the national pursuit of science, allied through the vehicle of the MeerKAT National Park with environmental conservation; on the other, the rejuvenation of a local economy facing significant challenges tied up with hopes for redress. Exacerbating the tensions are the SKA's specific requirements to reduce human-produced radio frequency interference, most acutely in and around the core infrastructural site, which dramatically narrow possibilities for future economic development in the area outside what radio astronomy can or will tolerate. Thus, unlike with other conservation areas, it is not at all clear if and how the MeerKAT National Park

declared around the SKA project is compatible with the promotion of astro-tourism and nature conservation tourism in lieu of livestock farming. While optical astronomy can coexist relatively easily with other land uses, provided light pollution is kept under control, radio astronomy has extremely stringent requirements of its environment: it cannot function optimally in the same physical space as many other contemporary technologies such as mobile phones, Wi-Fi systems, petrol-powered cars, wind turbines, satellites, and aircraft. For this reason restrictions on other land uses in and around the core site are not only much stricter than those required by optical observatory but also operate on a much larger scale – with the potential, ultimately, to shape development options throughout the Northern Cape as a result of the Astronomy Geography Advantage Act.

It is for these reasons that "astronomy for development" cannot be assumed to be the simple corollary of "the development of astronomy." If one accepts this, what then is the scope and content of national commitments to inclusive and sustainable development "for all" in the shadow of one of the country's flagship project in S&T, where the power to define the future of the region does not lie with the people most directly affected by its earthly footprint?

What this discussion should also make clear is that at their core, the tensions generated by the institutionalisation of the SKA in the Northern Cape are not between science and anti-science, but, rather, between recognition and non-recognition, actor and acted upon, space and place (on the latter see Walker 2019). What is significant here is the understanding of the Karoo among many powerful external observers as a wasteland – a largely empty space, far from the major cities, in which little of current value is taking place, hence an appropriate site for national development projects for the greater good. The national idea of emptiness has been carried through authoritatively in the international characterisation of the Karoo as a "desert region" on the SKA International website, where it is explained that this is what makes this location ideal from a scientific and technical point of view.[23] Tellingly, the projection of emptiness mirrors earlier representations of the region in the eighteenth century, that legitimated the colonial project in what at that stage constituted the Cape's historical Northern frontier (Penn 2005). Since then, the region has experienced a multi-layered history of external intrusions that has shaped the way in which claims to land and identity are framed in the contemporary period (see Chinigò 2019).

The declaration of an astronomy reserve around the SKA thus speaks to both the symbolic and the material aspects of this area as a sacrifice zone. It frames the ways in which the pursuit of astronomy for development intersects with and attempts to control other land uses. Radio astronomy's incompatibility with the deployment of modern technologies outside its purview puts it in direct competition with existing and potential land uses (including, interestingly, shale-gas mining or "fracking," on which see ASSAF 2019). At the same time, the reserve reinforces dominant views of the Karoo as historically empty land with little intrinsic value, in which other forms of human activity can be restricted or regulated in order to undertake nationally and globally significant science. Revealingly, in a national context in which the issue of land ownership and the future of land reform are highly politicised debates, the implications for land and agrarian reform of the Astronomy Geographic Advantage Act (affecting some 30% of the countryside) and the establishment of the SKA core site as a protected area have fallen under the political radar (Walker 2019).

This brings us to another feature of the SKA that is consistent with the idea of sacrifice

zones. Gastrow and Oppelt (2019) argue that the SKA has conceptualised its local development mandate in a tacit way, meaning that it assumes that positive local repercussions are consequential upon the building of the core site infrastructure, i.e., a direct result or necessary outcome of the project's implementation. This logic is based on an essentially technocratic and depoliticised approach to local development in terms of "outreach activities" and local economic spin-offs, based on expert appraisals of local needs. In this approach development outcomes are measured and evaluated in aggregated, quantitative terms, using indicators derived from the national benefits which are extended logically to the region hosting the telescope. Thus, according to a SKA document summarising its impact in the Northern Cape up until the end of 2016, by that stage the project had mobilised a total investment of R220 million.[24] A significant portion of this investment has involved spending on local suppliers, as well as technical and professional training, the provision of internet connectivity to 219 farms, and the creation of 7,284 jobs (but with no breakdown of how many of these jobs were permanent and what skill levels were involved). A major component of local outreach activities is linked to the DST's Human Capital Development Programme (HCDP), a nation-wide scheme since 2005 to develop the capacity required to build and operate the SKA, through sponsoring grants and bursaries to scientists, engineers, artisans, and technicians at post-doctoral, postgraduate, and undergraduate levels.[25] In the region around the SKA's core site, the HCDP has been translated into various forms of support to eight schools in the towns of Carnarvon, Williston, Loxton, Vosburg, and Brandvlei, including a number of bursaries for further study for local school children showing promise in maths and science.[26] In Carnarvon, the SKA has sponsored a new computer lab with internet connectivity, as well as established the SARAO Visitors Centre in 2018.

> Our point here is not to dismiss these initiatives but to point out their logic and their associated limitations. While potentially valuable in themselves, these interventions derive from the SKA's science mandate and are limited in reach and in scope in relation to local priorities and local needs. This brings us to a discussion of the nature of public engagement between SKA and local people.

## The nature of public engagement

Addressing the role of science institutions in promoting public understandings of science, Jack Stilgoe, Simon Lock, and James Wilsdon (2014) have noted that the adoption of more participatory processes since the 1990s reflects a shift from approaches based on advancing "understanding" to ones premised on "engagement." They argue, however, that in many cases this transition is largely an incomplete process:

> It has been relatively easy to make the first part of the argument that monologues should become conversations. It has been harder to convince the institutions of science that the public are not the problem. The rapid move from doing communication to doing dialogue has obscured an unfinished conversation about the broader meaning of this activity. (Stilgoe, Lock, and Wilsdon 2014, 8)

Drawing on Bruno Latour's distinction between "matters of fact: and "matters of concern," they conclude that truly participatory processes of science engagement should stand on understanding of "The Public" less as a passive recipient and "more as a space within which publics selectively form around techno-scientific objects and matters of concern" (8).

We concur with this assessment, which, in the case of the SKA, requires that its engagement with its local Karoo publics should move beyond constructing them as recipients of information and/or problems to be managed, to a more dialogic encounter around local "matters of concern," that is to an encounter that acknowledges the trade-offs that have been demanded of them in terms of current needs and future options. To date, ambiguity about the scope of the participatory processes promoted as part of the SKA's local development mandate is exacerbating the tensions between SKA management and local people. At issue in many of the meetings that have taken place have been the terms of involvement in decision-making about the local development initiatives mobilised through the project. In the minds of local people, if the SKA is an instrument for transformation in their environment, then the planning and management of local development resources should follow a participatory process that goes beyond consultation and information. This expectation has clashed with the SKA's approach in terms of outreach and, increasingly, "stakeholder management" to ensure that the larger science project is not disrupted. At local public meetings organised by the SKA's project team a recurring concern voiced by local people has been the lack of transparency over the scope and future plans of the SKA (van der Hoef 2017; Butler 2018; Gastrow and Oppelt 2019; Terblanche 2020). The requirement for a much larger portion of land for the core site than was initially suggested in the early 2000s; the expectation that more jobs would be created, in a shorter period of time, than has occurred; the difficulty many local people have had in understanding the day-to-day work of scientists; the future management of jackals in the MeerKAT National Park around the SKA core site; multiple problems at the Carnarvon computer centre in 2016/17: compounded by poor communication, these concerns have generated cross-cutting layers of mistrust (on this see Terblanche 2020; van der Hoef 2017; Butler 2018). A major point of misunderstanding has been whether public participation meetings were about involving the public in deciding how to plan SKA-funded local development initiatives, or about communicating decisions about the rollout of the project and outreach activities that had already been taken elsewhere.

These concerns point to the significant ambiguities around the terms of the responsibilities for local development of the SKA as a national project[27] vis-à-vis the local state. Should a project of this magnitude take on tasks that the local state is mandated but has historically failed to fulfil, such as the provision of essential services and stimulating local economic development? In other words, should we regard the SKA as a proxy of the state when it comes to astronomy for (local) development? These questions illuminate the tensions among the different priorities, rationalities, and historical experiences that the institutionalisation of a multi-scalar big-science project like the SKA brings together, which we have explored here through the idea of the local site of the project as a sacrifice zone. While the global, national and local priorities of S&T policy are not necessarily always misaligned, the case of the SKA exposes the limitations of easy notions of inclusive and sustainable development for all flowing from the development of science (in this case radio astronomy). In this case, the national investment in astronomy has involved uncomfortable trade-offs for the people living in the SKA's Central Astronomy Advantage Areas, located as they are in a marginalised region of the country still grappling with an unresolved history of dispossession.

## Conclusion

In this article, we have argued that the relationship between science and inclusive development is not axiomatic, as South Africa's post-apartheid S&T strategy for astronomy suggests. While this strategy promotes a discourse about the mutually reinforcing

relationship between science and development, the actual dynamics on the ground are far more complex than this narrative admits. In highlighting these tensions, we have introduced the notion of sacrifice zone to bring the SKA's receiving area into focus in the analysis of the local impacts of this globally and nationally significant big-science project. Our argument is not that there has been no investment in local development issues by the SKA. Rather, what the notion of sacrifice zone brings to the fore is the authority of the development priorities driving the larger project, in which the inequalities of power between national and local constituencies in determining the outcome are evident.

However, if inclusive development is a foundational commitment of the post-apartheid state, then it should follow that any trade-offs between national objectives and local expectations of development require meaningful mitigation to compensate for the sacrifices incurred. In this concluding section, we offer some pointers to issues that we think a mitigation strategy aimed at promoting local development in the shadow of the SKA should prioritise.

Firstly, priorities for how the local trade-offs can be best mitigated have to emerge through a genuine public participation process based on engagement, as argued by Stilgoe, Lock, and Wilsdon (2014). Ultimately, the commitment to inclusive development is not just about recognising that there are different development priorities, not all of which may be compatible, but also about giving affected people a real voice in determining what the differences are and how they are to be managed. Rather than assuming that the project's local development agenda should be an extension of national S&T concerns, those responsible for driving this agenda should base their interventions on a thorough assessment of local needs, one that is fully participatory and takes into account the complex history of the region as well as its current socio-economic and ecological challenges. In the context of the SKA, transparency over the future plans of the project will also be key for rebuilding trust and promoting mutual understanding in its satellite communities.

Secondly, and linked to the previous point, there is an urgent need to strengthen the capacity of local and provincial government to play a far more robust and dynamic role in the negotiations over local development priorities, and to leverage the maximum benefit they can from the resources mobilised through the SKA investment, both nationally and internationally. There are a number of areas where local and provincial government, working together, could play a meaningful role. For instance, investment is desperately required in interventions addressing the pandemic of alcohol and substance abuse, including the scourge of foetal alcohol syndrome (Olivier, Curfs, and Viljoen 2016). Improving the local road infrastructure and subsidising local public transport connecting the towns around the infrastructure could also facilitate communication and intra-town mobility and thereby undergird new possibilities for local livelihoods. Long-term investment in education could extend beyond the STEM fields (science, technology, engineering, and mathematics), in ways that acknowledge the priorities but also the constraints of the local agriculture-based economy, while recognising that most local livelihood strategies are centred on the region's small towns.

Thirdly, the restructuring of the local economy that is required is taking place in a context characterised by persistent and highly racialised inequality. Currently, out-migration is the best option many young people have to pursue a better future. Reversing the brain drain should be a goal that applies not only to scientists and engineers at national level; investment in local development initiatives should be aimed at creating the conditions in which local people can imagine a different future for the Karoo and in the

Karoo. An urgent task here is serious investment in finding solutions to the significant problems generated for the local economy by radio astronomy's requirements for an operating environment that is free of radio frequency interference. One focus area should be astro-tourism, which has potential in the case of optical astronomy, as in the case of Sutherland, but is far less promising in the SKA's hinterland. Another involves agriculture – a truly inclusive development agenda would prioritise finding technical and policy- political solutions to support farming (at different scales) in and around the MeerKAT National Park.

This leads to a further set of issues related to land. The fact that the SKA is now the largest landowner and most powerful institutional actor in the region means that it needs to take responsibility for ensuring that two important national priorities are much better aligned than they are now: that of astronomy and that of land and agrarian reform, including the unresolved issue of land restitution. The current shift from farming to astronomy must be understood against a long and complex history of land dispossession in the region, with profound implications for contemporary identities, livelihoods, aspirations, and claims for redress. The new phase in the history of the Karoo that the construction of the SKA is initiating, characterised by a major restructuring of the political economy of the region, is generating considerable uncertainty and anxiety among local residents about the future. In this context, the tensions around the SKA project in the Karoo appear to be less about the dominance of astronomers and astronomy or science *per se* and more about the schism between what the SKA stands for at the global and national level and what it currently represents for the residents of its host region.

As we have argued elsewhere (Walker and Chinigò 2018), the SKA is a highly complex "assemblage," encompassing a variety of material and immaterial elements, including very different understandings of what constitutes "sustainable and inclusive development" for the communities surrounding its core site. Local understandings have, furthermore, been largely invisible in national debates on both the development of astronomy and astronomy for development. It is this erasure of the local that has led us to ask whether the Karoo region of the Northern Cape is not functioning, implicitly if not explicitly, as a national sacrifice zone for astronomy and to suggest that posing the question of local impacts in these terms opens up an important space for engaging with the challenge of mitigation.

## Notes

1. In mid-2019, reflecting the emphasis on innovation, the Department of Science & Technology (DST) was renamed the Department of Science & Innovation (DSI). We have retained the "DST" term in the text where the documents and policies we cite were issued under this name.
2. MeerKAT, as described further below, is the South African designed 64-telescope array that is the precursor to the SKA proper.
3. This point derives from research by two postgraduate students in the DST/NRF Research Chair in the Sociology of Land, Environment and Sustainable Development: Boitumelo Malope in Loeriesfontein and Stef Borchardt in De Aar, both Karoo towns that are adjacent to or nearby major renewable energy projects that are designed to feed into South Africa's national electricity grid rather than address local energy challenges.
4. This history and its scientific legacy raise fascinating issues to explore further in relation to contemporary debates on the decolonisation of knowledge which are beyond the scope of this article but which we flag for further analysis.

5. See www.cosmopolitankarroo.co.za. Here we wish to acknowledge in particular participants at the workshop on "Karoo Futures? Global Science, Astronomy and the Square Kilometre Array (SKA)," hosted by the Chair at Stellenbosch University on 22–February 23 2018, which led to the – 2019 special issue of the *Journal of Southern African Studies* 45 (4), entitled "Karoo Futures: Astronomy in Place and Space."
6. See https://www.skatelescope.org/news/founding-members-sign-ska-observatory-treaty/.

   Accessed March 26 2019. In October 2020, the 13 member countries were Australia, Canada, China, Germany, France, India, Italy, The Netherlands, Portugal, South Africa, Spain, Sweden and the UK; the seven signatories to the March treaty were Australia, China, Italy, the Netherlands, (newcomer) Portugal, South Africa and the UK.
7. See https://www.ska.ac.za/science-engineering/meerkat/. Accessed February 22 2019.
8. While most of the antennas are to be built on the land owned by the state, the design calls for the erection of some dish antennas along three "spiral arms" that will extend outwards from the core site into the surrounding countryside, over which the state will secure servitude rights from the farm owners. Figure 1 provides a graphic representation of what is planned.
9. Data from each telescope are sent to correlators, a network of high-speed computers that combine and synchronise the signals from multiple telescopes. See https://www.skatelescope.org/signal-processing-2/. Accessed March 28 2019.
10. Similar issues have been discussed by Jon Agar in "Science and Spectacle" in the case of the Jodrell Bank observatory near Manchester (Agar 2014). Chapter 5, "Clearing the Ground," addresses the implications of policies restricting radio interferences for the region around the telescope.
11. For instance, see https://theconversation.com/astronomy-for-africa-the-ska-will-lead-to-brain-gain-7289. Accessed March 28 2019.
12. See http://www.dirco.gov.za/department/african_renaissence/index.htm. Accessed February 22 2019.
13. For more information see https://www.ska.ac.za/science-engineering/avn/.
14. List of participating countries, can be found here https://www.skatelescope.org/participating-countries/. Accessed October 29 2019. The financing of the SKA is a subject for further research. In 2016, the SKA Board of Directors put a cap of 674 million euros for the first phase of the 2-phase project ("Frequently asked Questions about the SKA." https://www.skatelescope.org/frequently-asked-questions/. Accessed October 19 2019) but there are concerns about escalating costs. In July 2019 the New Zealand government announced it was pulling out of the project because of concerns about delays and mounting costs, see https://physicsworld.com/a/new-zealand-pulls-out-of-the-square-kilometre-array-after-benefits-questioned/. Accessed October 19 2019.
15. The implementation of the international project since 2012 has been a phased one. The period between 2012 and 2018 saw the further development of the national investments in infrastructure already made by both South Africa and Australia, including the completion of South Africa's 64-dish MeerKAT in 2018. Phase one of the SKA proper in South Africa, currently gearing up, will see the expansion of this investment to a total of some 200 antenna dishes in and around the core site. Phase two is projected to start in the late 2020s and will see the extension of the array to the eight African countries that joined the project through the AVN programme.
16. In 2011, the four towns combined population was 14,560 (obtained from RSA 2011). The total population of the 3 local municipalities most directly affected by the SKA and the Karoo Central Astronomy Advantage Areas was a little over 45,000 in 2011 (see Walker et al. 2018, 159).

17. The build involved first the construction of KAT-7, as part of South Africa's bid to host the SKA, and then the 64-dish MeerKAT, once the bid had been awarded.
18. The spiral arms are part of the design of the SKA but, at this stage at least, the affected land is to remain in private ownership; here the servitude agreements will cover the SKA's rights of access to the affected farms to instal and run additional antenna dishes.
19. See for instance http://savethekaroo.com/. Accessed February 21 2019.
20. For more details about the land acquisition process see http://www.ska.ac.za/about/land-acquisitions/. Step 5 defines the conditions under which the right of expropriation can be exercised.
21. For a discussion on this in relation to the national politics of land reform see Walker (2019).
22. One example is the now retired pastor of the United Reformed Church (URC) in Carnarvon. See https://www.pa.org.za/write/message/185/. Accessed October 29 2019.
23. See https://www.skatelescope.org/africa/. Accessed October 29 2019.
24. Considering 2008 as the start of operations in the Northern Cape, the project mobilised an annual investment of approximately 24.4 million ZAR. See http://www.ska.ac.za/wp-content/uploads/2017/03/ska_investment_northern_cape_2017.pdf. Accessed March 11 2019.
25. Nationally, as of 2017, the HCDP distributed 943 grants entailing a total investment of 446 million ZAR (Gastrow and Oppelt 2019).
26. See http://www.ska.ac.za/wp-content/uploads/2017/03/ska_investment_northern_cape_2017.pdf. Accessed March 11 2019.
27. We would argue that the issue of the responsibilities of the international SKA, which is largely invisible at this stage, also arises but that argument goes beyond the focus of this article.

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